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Washington, DC, *15 December 1989*

Change
No. 1

RIGID PAVEMENTS FOR AIRFIELDS

TM 5-825-3/AFM 88-6, Chap. 3 has been changed as follows:

1. New or revised material is indicated by a vertical line in the margin.

2. Remove old pages and insert new pages as indicated below:

Remove Pages	*Insert Pages*
i and ii	i, ii, iii and iv
1-3 and 1-4	1-3 and 1-4
2-1 and 2-2	2-1 and 2-2
2-5 and 2-6	2-5 and 2-6
2-11 and 2-12	2-11 and 2-12
3-1 and 3-2	3-1 and 3-2
3-5 and 3-6	3-5 and 3-6
None	9-1

3. File this transmittal sheet in front of the publication for reference purposes.

The proponent agency of this manual is the Office of the Chief of Engineers, the United States Army. Users are invited to send comments and suggested improvements on DA Form 2028 to (CEEC-EG), WASH DC 20314-1000.

TECHNICAL MANUAL
TM 5-825-3
AIR FORCE MANUAL
AFM 88-6, CHAPTER 3

HEADQUARTERS
DEPARTMENTS OF THE ARMY
AND THE AIR FORCE
WASHINGTON, DC *11 August 1988*

RIGID PAVEMENTS FOR AIRFIELDS

LIST OF ILLUSTRATIONS

By Order of the Secretaries of the Army and the Air Force:

CARL E. VUONO
General, United States Army
Chief of Staff

Official:

WILLIAM J. MEEHAN II
Brigadier General, United States Army
The Adjutant General

LARRY D. WELCH, *General, USAF*
Chief of Staff

Official:

WILLIAM O. NATIONS, *Colonel, USAF*
Director of Information Management
and Administration

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1-9. Base courses

a. General. Base courses may be required for one or more of the following reasons: (a) to provide uniform bearing surface for the pavement slab; (b) to replace soft, highly compressible, or expansive soils; (c) to protect the subgrade from detrimental frost heaving (in areas subject to frost action, design will be in accordance with TM 5-818-2/AFM 88-6, Chap. 4); (d) to produce a suitable surface for operating construction equipment during unfavorable weather; (e) to improve the foundation strength (modulus of soil reaction or modulus of elasticity); (f) to prevent subgrade pumping; and (g) to provide drainage of water from under the pavement. A minimum base course thickness of 4 inches will be required over subgrades that are classified as CH, CL, MH, ML, and OL (MIL-STD-619) for protection against pumping except in arid climates where experience has shown no need for the base course to prevent pumping. In certain cases of adverse moisture conditions (high water table or poor drainage), SM and SC soils may also require base courses to prevent pumping. Engineering judgment must be exercised in the design of base course drainage to ensure that water is not trapped directly beneath the pavement, which invites the pumping condition that the base course is intended to prevent. In addition, base courses in inlay sections should be constructed so as to drain toward the outside edge. Daylighting of the base course may also be required. Care must also be exercised when selecting base course materials to be used with slipform construction of the pavement. Generally, slipform pavers will operate satisfactorily on materials meeting base course requirements. However, cohesionless sands, rounded aggregates, etc., may not provide sufficient stability for slipform operation and should be avoided if slipform paving is to be a construction option. The designer should consider extending the base course 5 to 10 feet outside the edge of the pavement to provide a working platform for construction equipment.

b. Material requirements. A complete investigation will be made to determine the source, quantity, and characteristics of available materials. The base course may consist of natural materials or processed materials, as defined in TM 5-825-2/NAVFAC DM 21.3/AFM 88-6. In general, the unbound base material will be a well-graded, high-stability material. All base courses to be placed beneath airfield rigid pavements will conform to the following requirements in addition to those requirements in base course guide specifications (sieve designations are in accordance with American Society for Testing and Materials (ASTM) E 11):

— Well -graded, coarse to fine.
— Not more than 85 percent passing the No. 10 sieve.
— Not more than 15 percent passing the No. 200 sieve.
— PI not more than 8 perrcent.

However, when it is necessary that the base course provide drainage, the requirements set forth in TM 5-820-2/AFM 88-5, Chap. 2 will be followed.

c. Compaction requirements. High densities are essential to keep future consolidation to a minimum, but thin base courses placed on yielding subgrades are difficult to compact to high densities. Therefore, the design density in the base course materials should be the maximum that can be obtained by practical compaction procedures in the field but not less than:

— 95 percent of CE-55 maximum density for base courses less than 10 inches thick.
— 100 percent of CE-55 maximum density in the top 6 inches and 95 percent of CE-55 maximum density for the remaining thickness for base courses 10 inches or more in thickness.

d. Evaluation. The supporting value of base courses will be determined in accordance with paragraph 1-11.

1-10. Soil stabilization or modification

a. General. The stabilization or modification of the subgrade and/or base course materials using either chemicals or bitumens has been found desirable in many geographic areas. Principal benefits include the reduction of rigid pavement thickness requirements, provision of an all-weather construction platform, decreased swell potential, and reduction of the susceptibility to pumping as well as the susceptibility of strength loss due to moisture. Normally, the decision to stabilize or modify a soil will be based upon the economics involved, but in certain instances, such as the construction of inlay pavements, stabilization of the foundation will be required to facilitate construction. A lean concrete base is considered a stabilized layer and must meet the strength and durability requirements for a stabilized layer.

b. Requirements. To be considered a stabilized layer with a reduction in rigid pavement thickness, the stabilized material must be a minimum of 6 inches in thickness and meet the strength and durability requirements contained in TM 5-822-4/AFM 88-7, Chap. 4. Otherwise, the layer is considered to be a modified soil. The design of the stabilization or modification will be in accordance with TM 5-822-4/AFM 88-7, Chap. 4, and TM 5-818-2/AFM 88-6, Chap. 4. Where lean concrete base courses are being used, the mix proportioning, control, and testing of the lean concrete will be the same as for concrete. Since lean concrete bases are designed specifically to provide economy in pavement construction, emphasis must be placed on economy when arriving at the design mix. Experience has demonstrated that cement contents in the 225 to 375 pounds per cubic yard range yield economical lean concrete mixed with good workability. Pavement designs that result in a nonstabilized (pervious) layer sandwiched between a stabilized or modified soil (impervious) layer and the pavement present the danger of entrapped water with subsequent instability in the nonstabilized layer. These designed will not be used unless the nonstabilized layer is positively drained, and their use will require the approval of the Commander, U.S. Army Corps of Engineers (CEED-EG), Washington, DC 20314-100, or the appropriate MACOM.

Table 1-1. Typical values of modulus of soil reaction.

Type of material	Modulus of soil reaction (pci) for moisture content percentage							
	1 to 4	5 to 8	9 to 12	13 to 16	17 to 20	21 to 24	25 to 28	Over 28
Silts and clays, LL greater than 50 (OH, CH, MH)	—	175	150	125	100	75	550	25
Silts and clays LL less than 50 (OH, CL, ML)	—	200	175	150	125	100	75	50
Silty and clayey sands (SM and SC)	300	250	225	200	150	—	—	—
Sand and gravelly sands (SW and SP)	350	300	250	—	—	—	—	—
Silty and clayey gravels (GM and GC)	400	350	300	250	—	—	—	—
Gravel and sandy gravels (GW and GP)	500	450	—	—	—	—	—	—

Notes:

1. Values of k shown are typical for materials having dry densities equal to 90 to 95 percent of the maximum. For materials having dry densities less than 90 percent of the maximum, values should be reduced by 50 pci, except that a k of 25 pci will be the minimum used for design.
2. Values shown may be increased slightly if density is greater than 95 percent of the maximum, except that a k of 500 pci will be the maximum used for design.
3. Frost-melting-period k values are given in TM 5-818-2/AFM 88-6, chapter 4.

of the partially bonded rigid overlay equation as described in chapters 2, 3, and 4. In both cases, the thickness and flexural modulus of elasticity of the stabilized material will be determined at the same age as for the design flexural strength of the concrete. The flexural modulus of elasticity of cement-, lime-, and fly ash-stabilized material will be determined by ASTM C 78; whereas, for bituminous-stabilized material, the flexural modulus will be determined in accordance with appendix B of this manual.

1-11. Evaluation of foundation support

a. Modulus of soil reaction. the modulus of soil re-

CHAPTER 2
PLAIN CONCRETE PAVEMENT DESIGN

2-1. Basis of design

The thickness requirements for plain concrete pavements are based on the Westergaard edge loading analysis, which has been modified based upon full-scale accelerated traffic testing, small-scale model testing, and experience. The thickness design curves include an assumption that the stress at the edge of the loaded slab will be reduced 25 percent by the load transfer afforded by the joint designs required. A further assumption has been made that the flexural modulus of elasticity and Poisson's ration of the concrete remain constant at 4 x 10^6 pounds per square inch (psi) and 0.15, respectively. Analyses are availabe to accommodate other percentages of edge stress reduction, traffic volumes, and concrete properties than those used for preparation of the design curves and can be obtained from the Commander, U.S. Army Corps of Engineers (CEEC-EG), Washington, DC 20314-1000, or HQ Air Force Engineering and Services Center (AFESC/DEMP), Tyndall AFB, FL 32403-6001. In frost areas, special design requirements in addition to those stated in this chapter are in TM 5-818-2/AFM 88-6, Chap. 4.

2-2. Uses

Plain concrete pavements, meeting the requirements contained herein, can be used for any pavement facility. The selection of the pavement type should be based upon the economics involved. The only restriction to the use of plain concrete pavement pertains to unusual conditions that may require minimal reinforcement of pavement as outlined in chapter 3.

base courses or subgrade, the thickness requirement will be determined from the appropriate design curve using the design parameters of concrete flexural strength, R; modulus of soil reaction, k; gross weight of aircraft; aircraft pass level; and pavement traffic area type (except for shoulder design). The design gross aircraft weight and pass level may vary depending upon the type of traffic area or pavement facility. When the thickness from the design curve indicates a fractional value, it will be rounded to the nearest full- or half-inch thickness. Values falling exactly on 0.25 or 0.75 inch will be rounded upward. The minimum thickness of plain concrete pavement will be 6.0 inches. When it is necessary to change from one thickness to another within a pavement facility, such as from one traffic area to another, the transition will be accomplished in one full paving lane width or slab length.

c. Plain concrete pavements on stabilized base and/or subgrade. Stabilized base and/or subgrade layers meeting the strength requirements of paragraph 1-10 and lean concrete base will be treated as low-strength base pavements, and the plain concrete pavement will be considered an overlay with a thickness determiend using the following modified, partially bonded rigid overlay pavement design equation:

$$h_o = \sqrt[1.4]{h_d^{1.4} - \left[\left(\sqrt[3]{\frac{E_b}{E_c}}\right) h_b\right]^{1.4}} \qquad \text{(eq 2-1)}$$

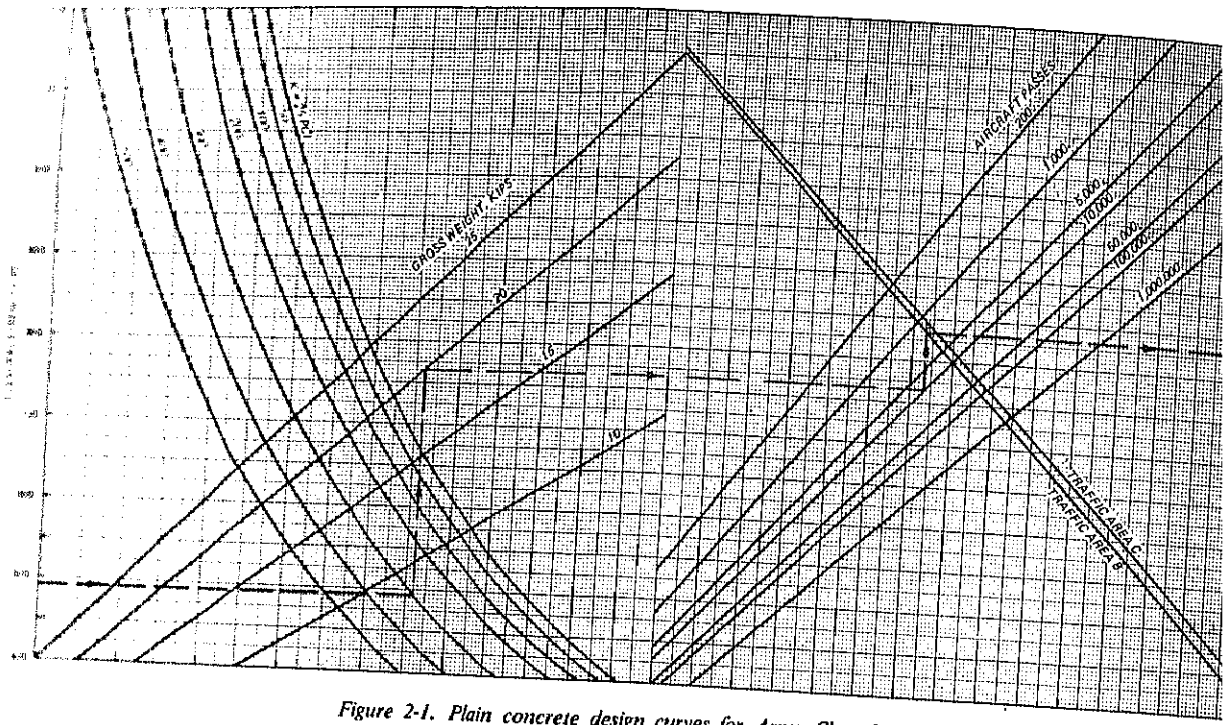

Figure 2-1. Plain concrete design curves for Army Class I airfields.

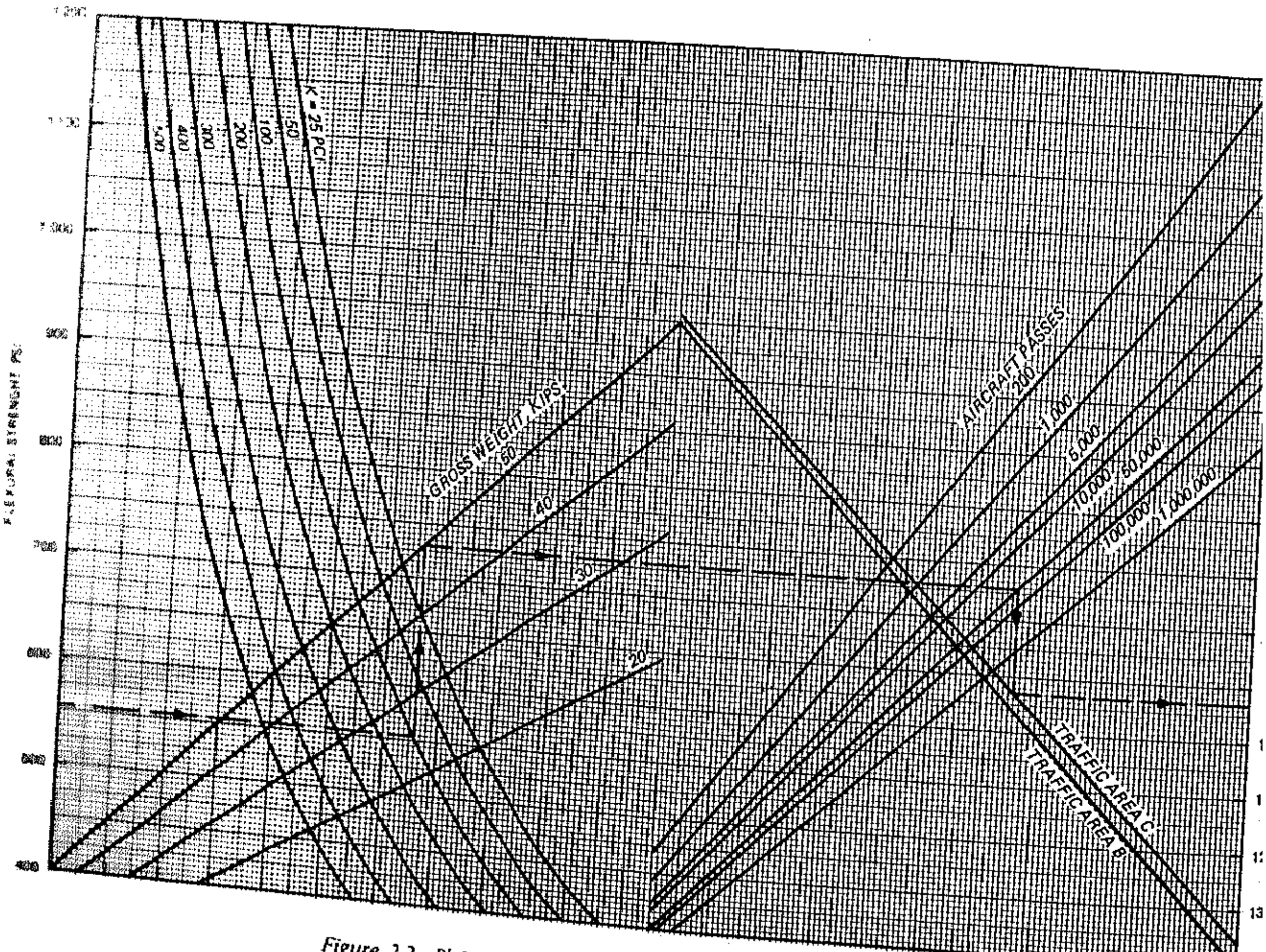

Figure 2-2. Plain concrete design curves for Army Class II airfields.

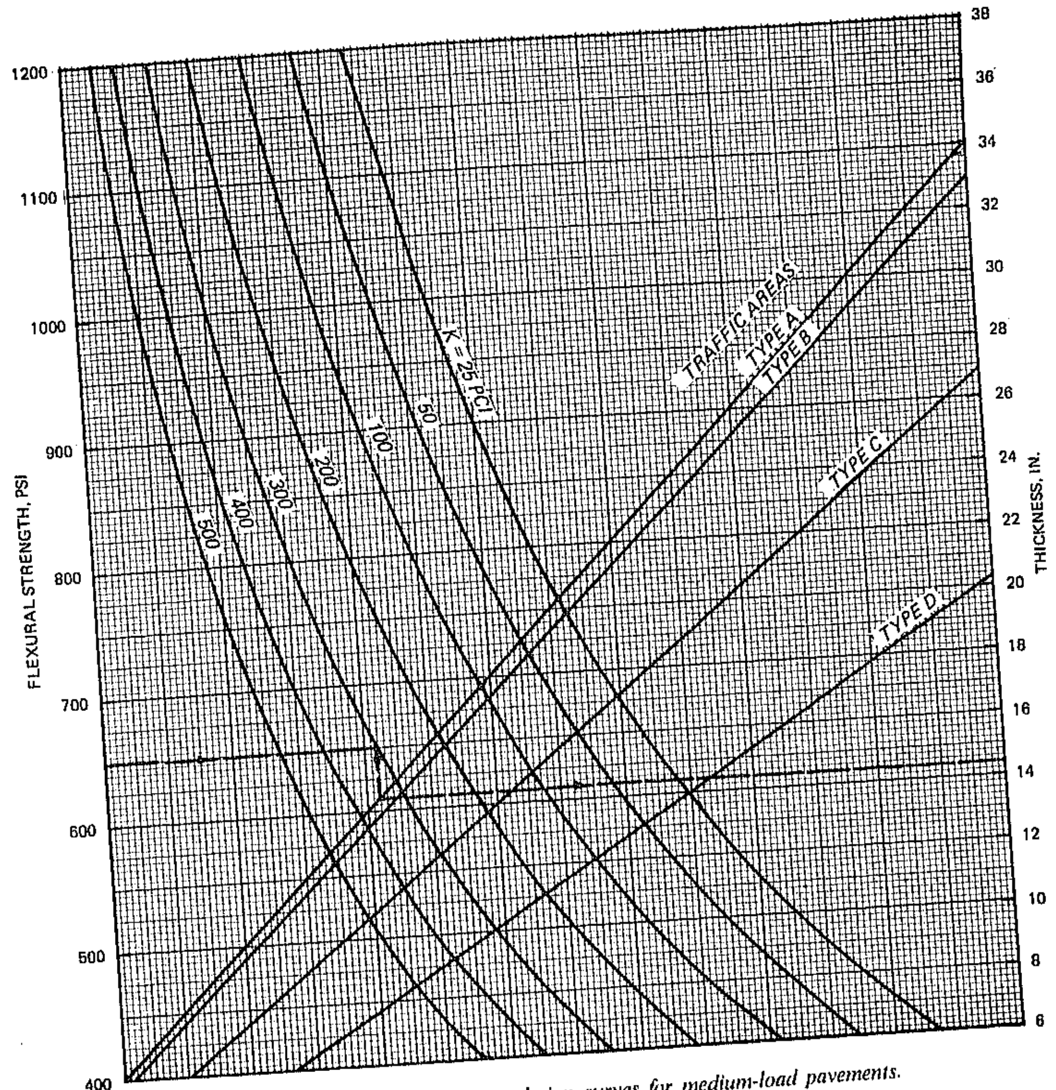

Figure 2-5. Plain concrete design curves for medium-load pavements.

ith dimension more than 25 percent. Under certain c conditions, joint spacings different from those in -1 may be satisfactory. Where it is desired to change int spacing, a request will be submitted to the iander, U.S. Army Corps of Engineers (CEEC-EG), ngton, DC 20314-1000, or the appropriate MACOM. Spacing of longitudinal contraction joints. Contraction will be placed along the center line of paving lanes iave a width greater than the determined maximum ng of transverse contraction joints in table 2-1. raction joints may also be required in the longitudinal tion of overlays, regardless of overlay thickness, to h joints existing in the base pavement unless a bond-king medium is used between the overlay and base ment or the overlay pavement is reinforced.

) Doweled and tied contraction joints. Dowels will equired in the last three transverse contraction joints ‹ from the ends of all runways to provide positive load isfer in case of excessive joint opening due to progressive wth of the pavement. Similar dowel requirements may included in the transverse contraction joints at the end other long paved areas, such as taxiways or aprons where local experience indicates that excessive joint opening may occur. In rigid overlays in Air Force Type A traffic areas and Army Type B traffic areas, longitudinal contraction joints that would coincide with an expansion joint in the base pavement will be doweled. Dowel size and spacing will be as specified in table 2-2. Deformed tie bars, ⅝-inch diameter by 30 inches long, spaced on 30-inch centers will be required in longitudinal contraction joints that fal 15 feet or less from the free edge of paved areas greate than 100 feet in width to prevent cumulative opening c these joints.

c. Construction joints

(1) General Construction joints may be required in bot the longitudinal and transverse direction. Longitudin construction joints (generally spaced 20 to 25 feet apa but may reach 50 feet apart depending on constructi equipment capability) will be required to separa successively placed paving lanes. Transverse constructi joints will be installed when it is necessary to stop concre placement within a paving lane for a length of time t will allow the concrete to start to set. All transve construction joints will be located in place of other regul

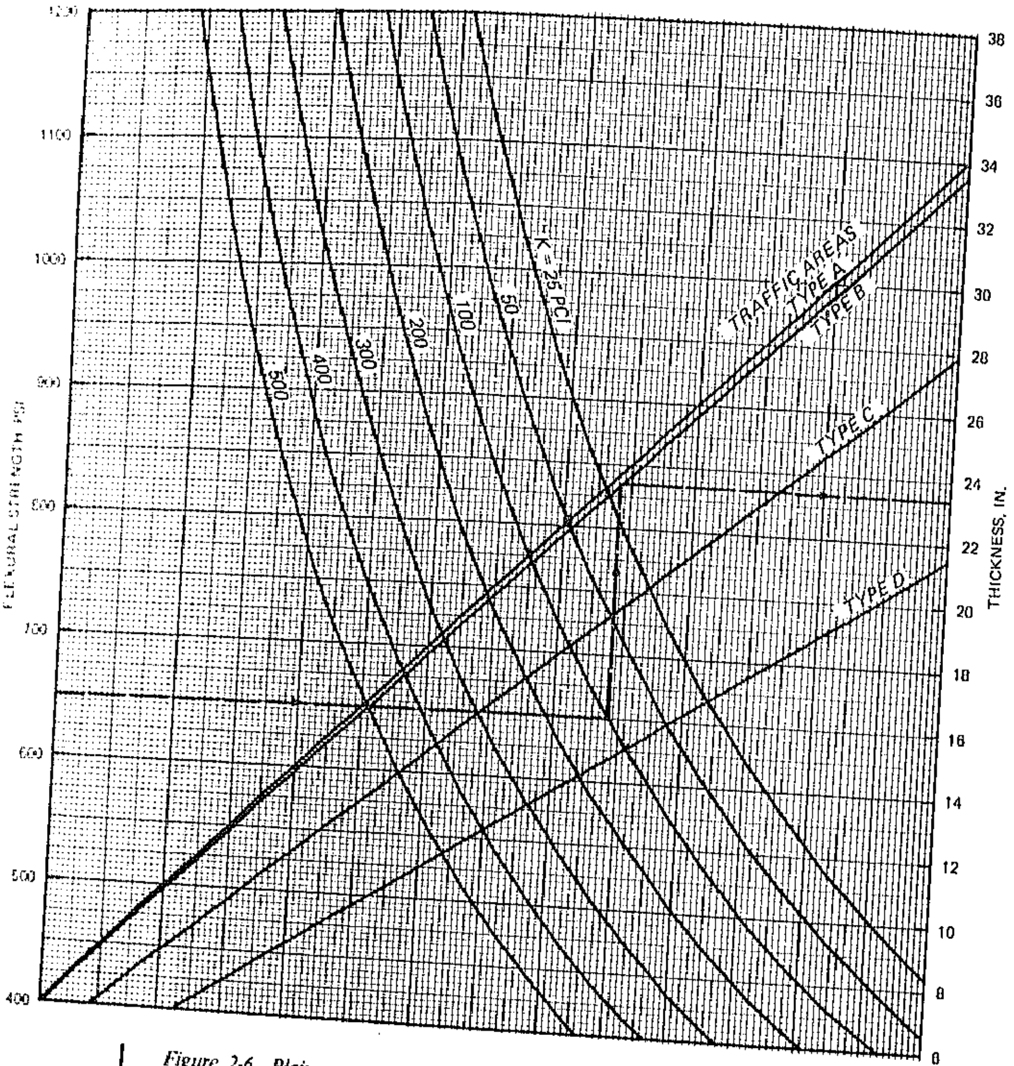

Figure 2-6. Plain conncrete design curves for heavy-load pavements.

...uation conditionns. Considering these factors, the types of construction joint that may be used are shown in figure 2-20.

(2) Doweled butt joint. The doweled butt joint is considered to be the best joint for providing load transfer and maintaining slab alinement. Therefore, it is the desirable joint for the most adverse conditions, such as heavy loading, high traffic intensity, and lower strength foundations. However, because the alinement and placement of the dowel bars are critical to satisfactory performance, this type of joint is difficult to construct, especially for slipformed concrete. The doweled butt joint is required for all transverse construction joints.

(3) Thickened-edge joint. Thickened-edge-type joints may be used in lieu of other types of joints employing load-transfer devices except as limited in figure 2-20. The thickened-edge joint is constructed by increasing the thickness of the concrete at the edge to 125 percent of the thickness determined from paragraph 2-3. The thickness is then reduced by tapering from the free-edge thickness to the design thickness at a distance 5 feet from the longitudinal edge. The thickened-edge butt joint is considered adequate for the load-in-

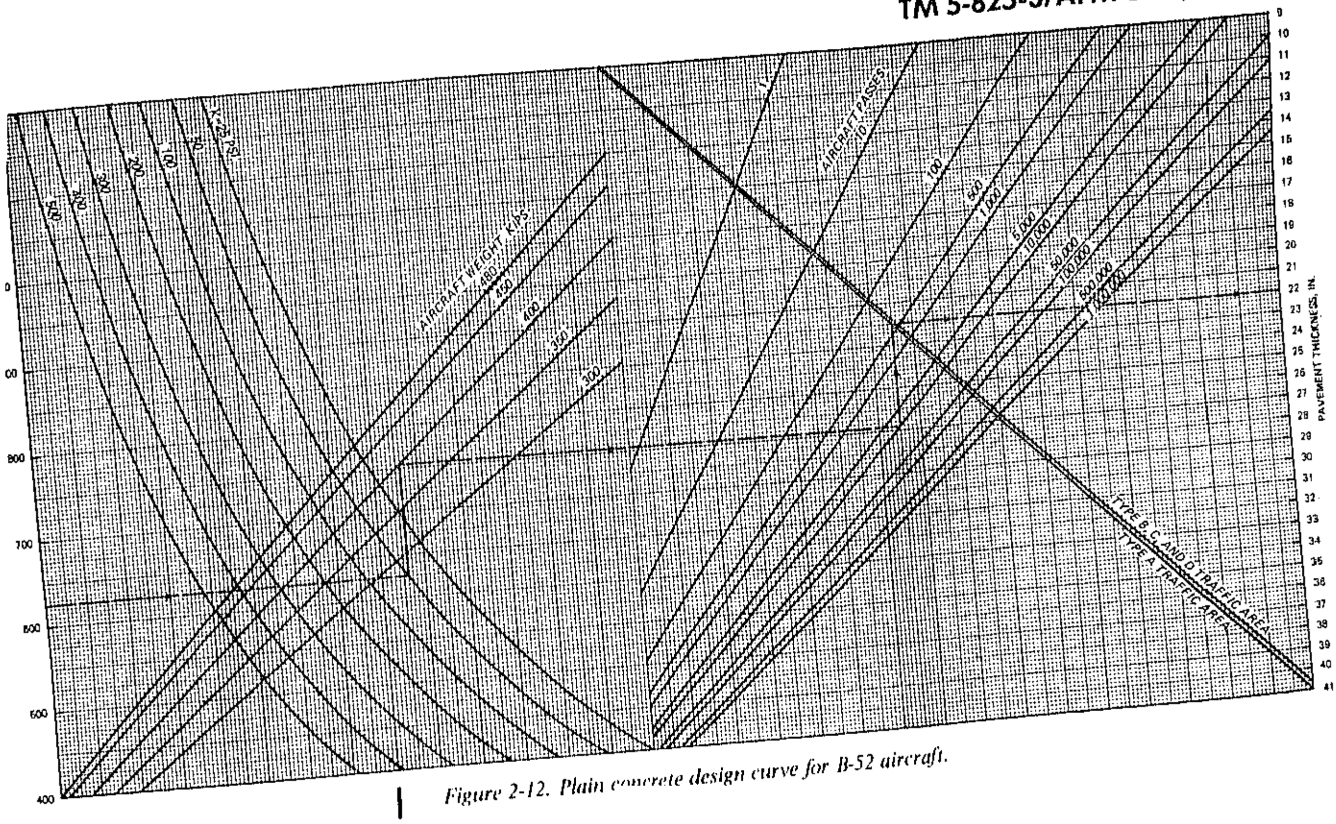

Figure 2-12. Plain concrete design curve for B-52 aircraft.

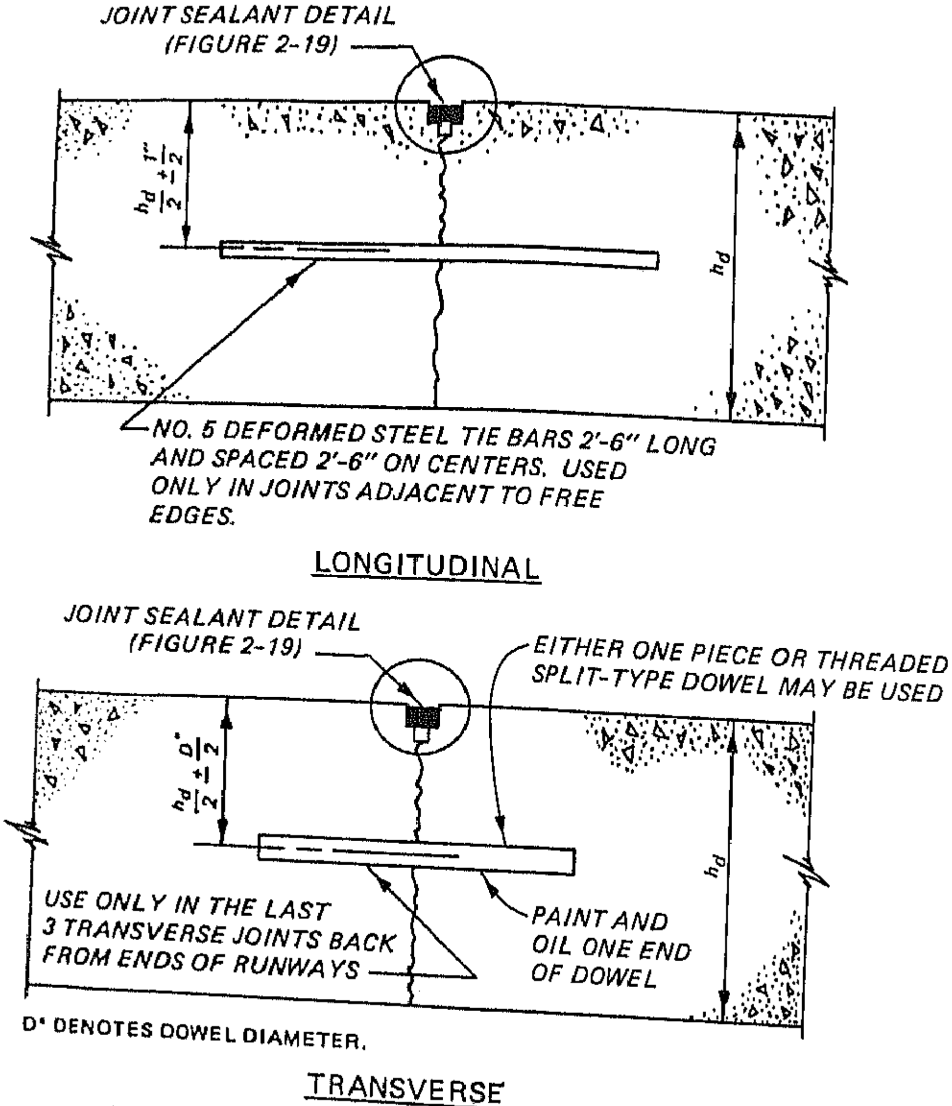

Figure 2-14. Contraction joints for plain concrete pavements.

dowels will be straight, smooth, and free from burrs at the ends. One end of the dowel will be painted and oiled to prevent bonding with the concrete. Dowels used at expansion joints will be capped at one end, in addition to painting and oiling, to permit further penetration of the dowels into the concrete when the joints close.

f. Special provisions of slipforming paving.

(1) Provisions must be made for slipform pavers when there is a change in longitudinal joint configuration. The thickness may be varied without stopping the paving train, but the joint configuration cannot be varied without modifying the side forms, which will normally require stopping the paver and installing a header. The requirements discussed as follows shall apply.

(2) The header may be set on either side of the transition slab with the transverse construction joint doweled as required. As an example, for the transition between the type A and type D areas on a medium-load pavement, the header could be set at the end of either type pavement. The dowel size and location in the transverse construction joint should be commensurate with the thickness of the pavement at the header.

(3) When there is a transition between a dowe longitudinal construction joint and a keyed longitudi construction joint, the longitudinal construction joint the transition slab may be either a keyed or doweled. T size and location of the dowels or keys in the transiti slabs should be the same as those in the pavement w the doweled or keyed joint, respectively.

(4) When there is a transition between two keyed join with different dimensions, the size and location of the k in the transition slab should be based on the thickne of the thinner pavement.

g. Joint sealing. All joints will be sealed with a suitab sealant to prevent infiltration of surface water and sol substances. Jet-fuel-resistant (JFR) sealants will be use in the joints of aprons, warm-up holding pad hardstands, washracks, and other paved areas where fu may be spilled during the operation, parking, maintenance and servicing of aircraft. In addition, heat-resistant JF joint sealant materials will be used fo

CHAPTER 3
REINFORCED CONCRETE PAVEMENT DESIGN

1. Basis of design

eel reinforcement in the concrete provides improved ntinuity across the cracks that develop because of vironmental factors or induced loads. The improved ack continuity results in better performance under traffic nd less maintenance than an equal thickness of plain oncrete pavement. Thus, for equal performance, the hickness of reinforced concrete pavement can be less than he thickness of plain concrete pavements. The design rocedure presented herein yields the thickness of einforced concrete pavement and the percentage of steel einforcement required to provide the same performance as a predetermined thickness of plain concrete pavement constructed on the same foundation condition. The procedure has been developed from full-scale accelerated traffic testing. Failure is considered to be severe spalling of the concrete along the cracks that develop during traffic.

3-2. Uses

Reinforced concrete pavement may be used as slabs on grade or as overlay pavements for any traffic area of the airfield. Reinforcement may be used to reduce the required thickness and permit greater spacing between joints. Its selection should be based upon the economics involved. In certain instances, reinforcement will be required to control cracking that may occur in plain concrete pavements without any reduction in thickness requirements.

3-3. Reduced thickness design

a. General. The greatest use of reinforcement to reduce the required plain concrete pavement thickness will probably be to provide a uniform thickness for the various traffic areas and to meet surface grade requirements. This is especially true for rigid overlays where it is necessary to provide different thicknesses for the various types of traffic areas as different structural conditions of the base pavement. Since these changes in thickness cannot be made at the surface, reinforcement can be used to reduce the required thickness and thereby avoid the necessity for removal and replacement of pavements, or overdesigns. There are other instances in which reinforcement to reduce the pavement thickness may be warranted and must be considered, but the economic feasibility for the use of reinforcement must also be considered. The design procedure consists of determining the percentage of steel required, the thickness of the reinforced concrete pavement, and the maximum allowable length of slabs. In addition, the computer program discussed in chapter 9 may be used for the design of reinforced concrete pavement.

b. Determination of required percent steel and required thickness of reinforced concrete pavement. It is first necessary to determine the required thickness of plain concrete pavement using the design loading and physical properties of the pavement and foundation. When the reinforced concrete pavement is to be placed on stabilized or nonstabilized bases or subgrades, the procedures outlined in chapter 2 will be used to determine the thickness of plain concrete. The thickness of plain concrete so determined will be used to enter figure 3-1 to determine the required percent steel and the required thickness of reinforced concrete pavement. Since the thickness of reinforced concrete and percent steel are interrelated, it will be necessary to establish a desired value of one and determine the other. The resulting values of reinforced concrete thickness and percent steel will represent a reinforced concrete pavement that will provide the same performance as the required thickness of plain concrete pavement. In all cases, when the required thickness of plain concrete pavement is reduced by the addition of reinforcing steel, the design percentage of steel will be placed in each of two directions (transverse and longitudinal) in the slab. For construction purposes, the required thickness of reinforced concrete must be rounded to the nearest full- and half-inch increment. When the indicated thickness is midway between full- and half-inch, the thickness will be rounded upward.

c. Determination of maximum reinforced concrete pavement slab size. The maximum length or width of the reinforced concrete pavement slabs is dependent largely upon the resistance to movement of the slab on the underlying material and the yield strength of the reinforcing steel. The latter factor can be easily determined, but very little reliable information is available regarding the sliding resistance of concrete on the various foundation materials. For this design procedure, the sliding resistance has been assumed to be constant for a reinforced concrete pavement cast directly on the subgrade, on a stabilized or nonstabilized base course, or on an existing flexible pavement. The maximum allowable width, W, or length, L, of reinforced concrete pavement slabs will be determined from the following:

$$W \text{ or } L = 0.0777\sqrt[3]{h_d(y_s S)^2} \quad \text{(eq 3-1)}$$

where

h_d = design thickness of reinforced concrete

y_s = yield strength of reinforcing steel, normally 60,000 psi

S = percent reinforcing steel

The formula above has been expressed on the nomograph (figure 3-1) for a steel yield strength, y_s, of 60,000 psi, and the maximum length or width can be obtained from the intersection of a straight line drawn between the values of design thickness and percent steel that will be used for the reinforced concrete pavement. The width of reinforced concrete pavement will generally be controlled by the concrete paving equipment and will normally be 25 feet unless smaller widths are necessary to meet dimension requirements.

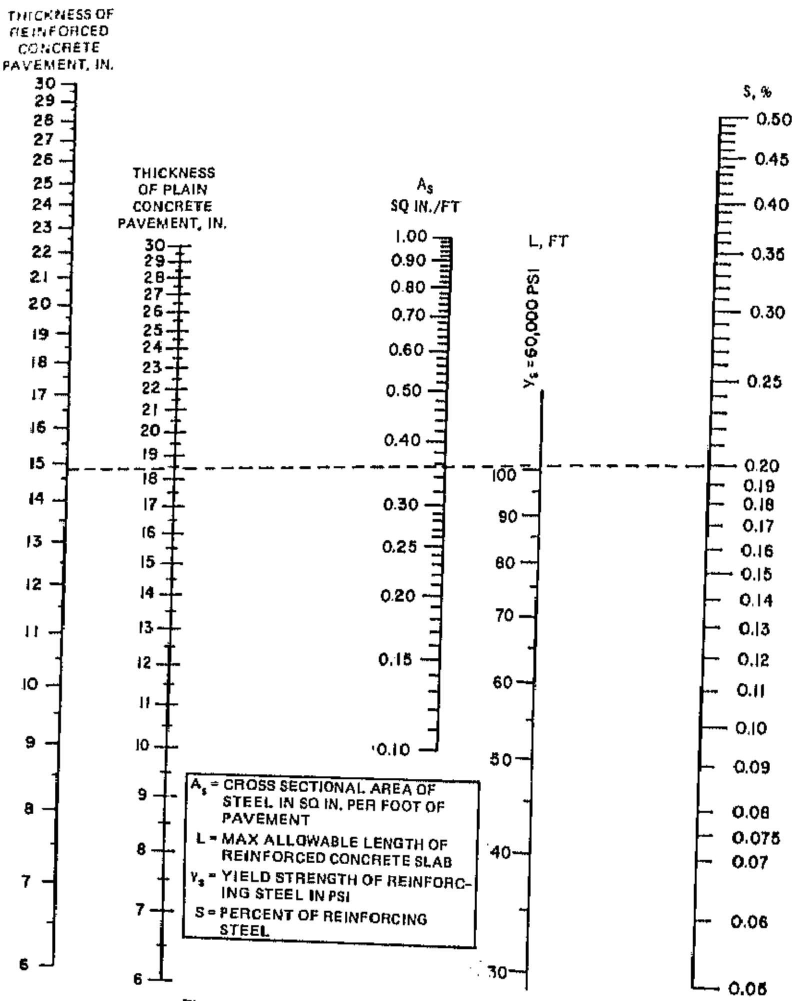

Figure 3-1. Reinforced concrete pavement design.

d. Limitations to reinforced concrete pavement design procedure. The design procedure for reinforced concrete pavements presented herein has been developed from a limited amount of investigational and performance data. Consequently, the following limitations are imposed:

(1) No reduction in the required thickness of plain concrete will be allowed for percentages of steel reinforcement less than 0.05.

(2) No further reduction in the required thickness of plain concrete pavement will be allowed over that indicated for 0.5 percent steel reinforcement in figure 3-1 regardless of the percent steel used.

(3) The maximum width or length of reinforced concrete pavement slabs will not exceed 100 feet regardless of the percent steel used or slab thickness.

(4) The minimum thickness of a reinforced concrete pavement or overlay will be 6 inches.

3-4. Reinforcement to control pavement cracking

a. General. Reinforcement is mandatory in certain pavement areas to control or minimize the effects of cracking. The reinforcing steel holds cracks tightly closed thereby preventing spalling at the edges of the cracks and progression of the cracks into adjacent slabs. For each of the following conditions, the slabs or portions of the slabs will be reinforced with 0.05 percent steel in two directions normal to each other unless otherwise specified. No reduction in thickness will be allowed for this steel.

b. Odd-shaped slabs. It is often necessary in the design of pavement facilities to resort to odd-shaped slabs. Unless reinforced, these odd-shaped slabs often crack and eventually spall along the cracks, producing debris that is objectionable from operational and maintenance viewpoints. In addition, the cracks may migrate across joints into adjacent slabs. In general, a slab is considered to be odd-shaped if the longer dimension exceeds the shorter one by more than 25 or if the joint pattern does not result in essentially a square or rectangular slab. Figure 3-2 presents typical examples of odd-shaped slabs requiring reinforcement. Where practicable, the number of odd-shaped slabs can be minimized by using a sawtooth fillet and not reinforcing.

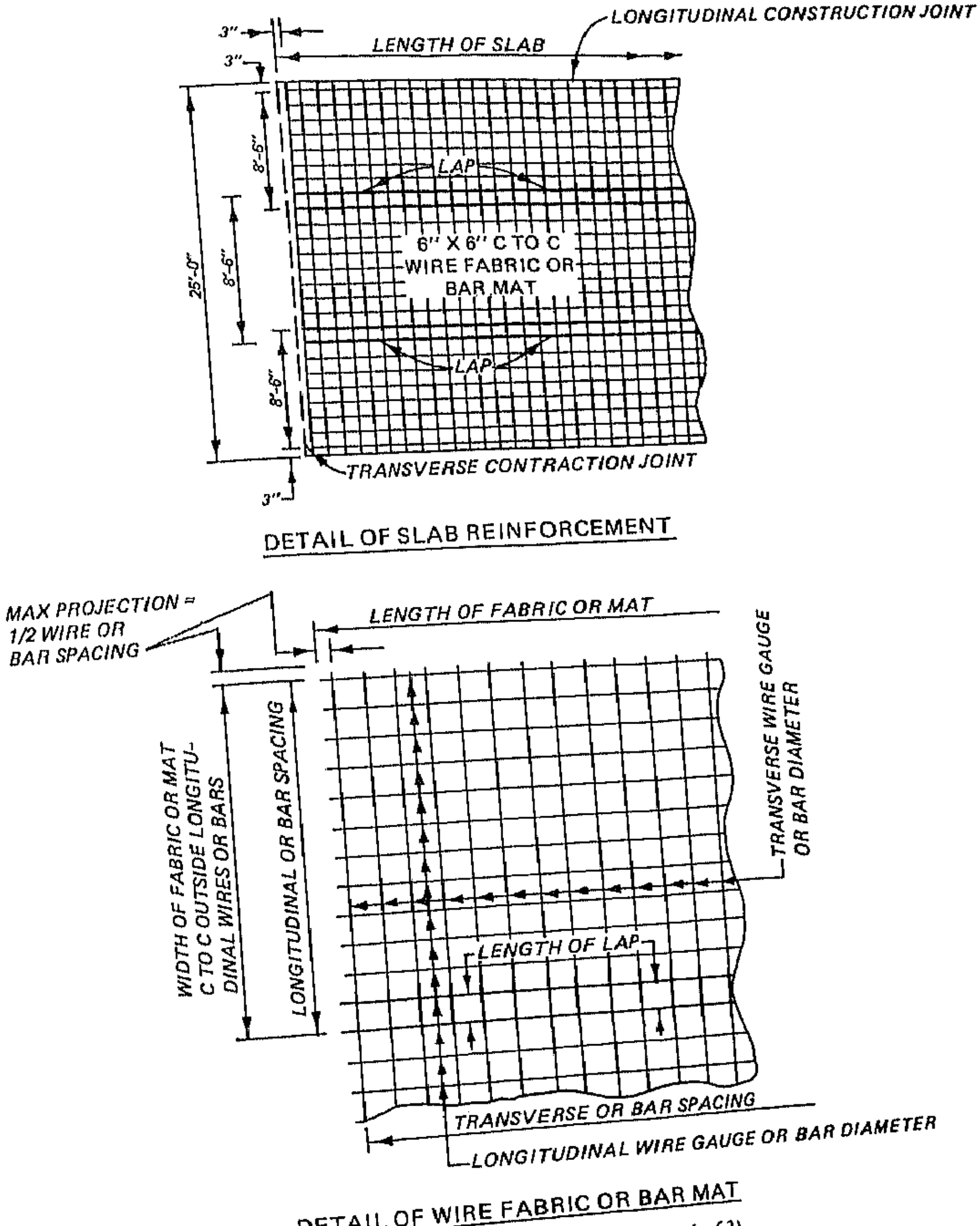

Figure 3-3. Reinforcing steel details. (Sheet 1 of 2)

storm drain inlets, and certain types of flush lighting fixtures. The entire slab or slabs containing the blockouts will be reinforced in two rectangular directions.

3-5. Reinforced concrete pavements in frost areas

Normally, plain concrete pavements in frost areas will be designed in accordance with TM 5-818-2/AFM 88-6, Chap. 4, and reinforcement will be unnecessary. There may, however, be special instances when it will be directed that the pavement thickness be less than required by frost design criteria. Two such instances are: the design of new pavements to the strength of existing pavement when the existing pavement does not meet the frost design requirements, and the design of an inlay section of adequate strength pavement in the center portion of an existing runway when the existing pavement does not meet the frost design requirements. In such instances, the new pavements will be reinforced with a minimum of 0.15 percent steel. The minimum 0.15 percent steel will be placed in each of two directions (transverse and longitudinal) in the slab. The reinforcing steel is required primarily to control cracking that may develop because of differential heaving. The pavement thickness may be reduced, and the maximum slab length, consistent with the percent steel, may be used. Longer slabs will help reduce roughness that may result from frost action. Greater percentages of steel reinforcement may be used when it is desired to reduce the pavement

CHAPTER 9
COMPUTER PROGRAM FOR RIGID PAVEMENT DESIGN

9-1. General

This chapter provides guidance in the use of the computer program for the design of plain and reinforced concrete pavements. A computer disk containing the design program is attached to this manual.

9-2. Development of program

a. A computer program was developed to aid in the design of military airfield rigid pavements. The program was developed on an IBM PC-AT using FORTRAN 77 as the developmental language with Microsoft's FORTRAN Compiler (version 3.2) and MS-DOS (version 3.1) as the operating system. Normally, the program will be furnished as a compiled program which can be executed from floppy diskettes or hard drives. Thus far all the programs have been found to run on IBM PC-AT or IBM compatible microcomputers containing a minimum of 512K RAM.

b. In development of the computer program, an effort was made to provide a user friendly program requiring no external instructions for use of the program. Aside from instructions for initiating execution, which is standard for any executable program, the user is lead through the design procedure by a series of questions and informational screens. The input data required for pavement design by the program is identical to the data required by the design manual, and the results obtained from the program should be close to the results obtained from the design curves. Because the computer program recalculates data and approximates certain empiracal data, there may be some minor differences in results from the program and from the manual. If significant differences are obtained, contact CEEC-EG.

c. The computer programs are date named i.e, the date of the latest revision is contained in the program name. The first digit of the number in the program name is the last digit of year of the revision. The last two digits of the program name is the month of the revision. Thus, the program RAD 810 was revised October 1988.

d. Care is to be taken that the latest version of the computer programs is being used. If there is doubt concerning a program, contact CEEC-EG.

e. Accompanying each program is an aircraft data file RADCRAFT.DAT, for design of rigid pavements. These data files contain all the aircraft data used by the programs. The data file has the capacity to hold data for a total of 50 different aircraft.